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ENGINEERING MANAGEMENT OF E-LABORTORY

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ABSTRACT

E-laboratories are having increasing applications all over the world. Engineering management of such laboratories has to start from clear definition of the purpose. This is followed by the pre-design arrangements; then to the various aspects of the design. After running such e-lab courses, the experience gained has to be evaluated. Different aspects of management of various steps are discussed in this paper. An example for e-lab experiments in electrical engineering is given. Evaluation of understanding of students using e-lab compared to normal labs is discussed. Online laboratories, however, are not as mature as online courses yet.

1. INTRODUCTION

With the recent progress of e-learning using the internet, a variety of technical subjects were among the courses covered by such method of learning. However such topics cannot be taught properly without exposure to some experimental work in order to lead the student to the practical aspects of the theoretical subjects he or she learns. Simulations of experimental setups or what is called virtual labs were used in many cases to give the student some feeling of what happens practically in the laboratories. However such simulations are in one way give a sort of artificial imitation of what happens in laboratories and on the other hand does not give the student enough confidence in the results he or she gets due to the prior knowledge that work is done on software rather than actual experimental equipment. For this reason a need is there for e-labs or what sometimes called remote labs in which actual experiments are performed to realize the interaction between the student and the laboratory equipment and to get the experimental results which are the same as those if he or she performed the experiment in the laboratory in person. However it is observed that the boundaries among the three types of labs (Normal labs, virtual and e-labs) are blurred in the sense that most laboratories are mediated by computers, and that the psychology of presence may be as important as technology [1].

Another advantage of e-lab is the possibility of getting access to expensive equipment (e.g., an electron microscope) or dangerous equipment (e.g. radiation equipment). Such access may be available on a 24- hour, 7-day basis from any where, giving the opportunity to use the equipment by students belonging to one or more educational institutions.

Online experimentation also develops engineering skills like remote operation, diagnosis and maintenance, and collaborative tele-working. These skills are becoming increasingly important for the students to acquire them for their future work environment with more and more jobs performed remotely [2].

Many experiments in electrical engineering education have no physical sensations; and can be conducted remotely over the Internet around the clock without video transmission or other methods requiring high transfer bandwidth. In experiments with short time constants, several students can share the same remote hardware [3].

Remote laboratories can be used in different ways. It can be shared by many institutions and students worldwide [4]. It may serve different laboratories in the same institution. Remote lab may also be used by the teachers themselves during live traditional lectures to better demonstrate physical concepts, by simple connection to the remote lab and explaining to the students while running the experiments in step by step manner.

Remote experiments may also enable students to gain international collaboration and intercultural communication skills by providing an opportunity to collaborate with overseas students [5].

It is the expertise of the designer of e-lab to overcome difficulties arising in remote labs by trying to create similar feeling for the remote student to that when working in real atmosphere of the lab, as well as the possibility of enabling the work together with other remote students in such a way that will enable actual remote collaboration.

A lot of effort and cost are needed for starting an e-lab. It is uneconomical to repeat the effort for each experiment or laboratory in the same institution. Hence the only way to make the Internet based laboratory system viable is to move toward a modularity concept. Under this strategy there needs to be a few modular hardware and software blocks that can be made easily adaptable to a range of engineering and engineering technology laboratory experiments [6]. A central service for a whole university must be installed and run by a central department. Leaving this tasks to single small projects is extremely inefficient, even worse, if different projects run their courses on different platforms, which are not interoperable (unfortunately, such a situation is not seldom found in universities) [7].

2. DEFINING THE AIM, SIZE AND PARTNERS OF THE E-LAB

The purpose of setting up e-laboratory and its general outlines has to be defined clearly. Is it for serving remote students experimentations; or is it also to serve lecturers in their live lecturing or researchers? Is there going to be joint efforts from more than one institution to share the cost and benefits of the laboratory? How big and complex is the laboratory or laboratories going to be served? Is the main cause for using the e-lab going to be the cost, i.e. the equipment is too expensive so as to raise its usability by various partners? When the purpose of the laboratory is to serve remote students, are the experiments going to be performed in groups? Is the laboratory going to be used by different departments in the institution or it is going to be specialized for one department or one field in the department? Does the institution own previous experience in e-learning and whether the e-experiments are going to serve a running theoretical e-course in parallel or it is to be served as a stand alone e-lab course independent of other courses?

All these matters and much more related to the platform, communications, etc. have to be addressed and discussed before trying to start e-lab facilities in the institution. Once the purpose and the scope become clear, design of the system can start.

3 DESIGN PHASE

Typical online Internet accessible laboratory consists of lab devices, instruments or pilot plant equipment, teleconferencing equipment (or at least built-in chatting capabilities for collaboration among students and instructor), control software allowing users to perform experiments, lab scheduling component assigning users time to use the lab, work assignments for students and tutorial background information on the experiments, including instructions on how to run the experiment [2]. This means that the system consists usually of : a) Experiments; b) Interfacing; c) GUI and Web Publication; d) Server; e) Internet delivery; and f) Client computer [8].

3.1. Experiments

In fact there are three categories of laboratory experiments. These three categories of experiments need different types of lab sessions and, hence, require different software architectures.

1) Batched Experiment where the student specifies all parameters that govern the execution of the experiment before the experiment starts.

2) Sensor Experiment where the student usually can not specify any parameters although he/she may be able to select the particular sensor data that student wishes to receive.

3) Interactive Experiment; in which an interactive experiment or run-up of pilot plant, the student typically sets a series of parameters, initiates the experiment, and then monitors the experiment's course or pilot plant operation, changing control and tuning parameters as necessary.

Conceptually, an interactive experiment can be thought of as a sequence of alternating control and monitoring intervals. In general, the control intervals have many of the characteristics of a batched experiment, and the monitoring intervals resemble sensor experiments [2].

Unfortunately, equipment used in different laboratories varies a lot from each other. However some laboratories belonging to the same department may use a lot of common equipments. The use of common equipment by different experiments or even by different parts of an experiment may be shared using some sort of matrix switch.

Along with the virtual instrument panels accessed over the internet, the students can also access a video feed from the lab to observe the changes in the instrument as parameters are varied on the virtual panel controlling the instrument. Use of video in observing the instrument behavior during control offers numerous advantages when controlling complicated experiments using remotely controlled moving objects. The camera may be focused or rotated by the remote user. Multiple cameras may be used if necessary.

Usually only one student can control the experiment from any one location, but other students from other locations can observe the physical sensations and perform parts of the experiments [3].

The modularity in system design will enable it to integrate with a large variety of physical laboratory experiments with very little cost and effort [8].

3.2. Software Design

An environment that can host or offer multiple online labs should be planed. This software may be in a form of a Learning Management System (LMS) which provides the basic functions needed for composition and delivery of any web-based educational system. It should offer: administration of users and courses, composition and delivery of content, communication, assessment, and grading. As a central service an LMS must be installed and run by a central department within the university.

As far as the student software; it is important to provide a user-friendly and effective GUI that can attract students while performing experiments without any physical supervision and assistance, which are usually provided during a traditional laboratory class. One of the common software used to serve a variety of experiments is LabVIEW (Laboratory Virtual Instrument Engineering Workbench). It is a powerful instrumentation and analysis programming language for PCs running Microsoft Windows and various operating systems [9]. LabVIEW provides a facility to develop a GUI called virtual instrument (VI), which can serve both of the above purposes [8]

Software should enable users to have full control of a web camera and can view instruments and components or just look around the laboratory [5].

A number of issues have to be resolved in the software. Among these are: number of participants i.e. to define if the lab is individual or for a group. For groups it is assumed that the students would work in a distributed scenario. Interaction tools should consider all possible interactions (students-students, student-tutor, tutor-student or student-contents). Beside interaction tools, many other tools should be considered to support the activity. The following should be considered: coordination module for accessing the experiment (schedule), discussion forum, text chat, voice chat, videoconference, content management, etc. All these tools could be joined in some Learning scheme [10]

4 IMPLEMENTATION PHASE

4.1. Experiment Setup

A variety of experimental setup has been reported in literature [1-16]. It seems that till now no unified philosophy for setting up experiments has been reached. Each laboratory deals with the problem from different point of view. It may take sometime for researcher to reach standard techniques for setups for similar experiments.

4.2. Switching Devices

The main usual hardware component that allows connection of selected circuit components is a relay matrix switch. As an example a 16x16 relay matrix module was chosen in reference [5]. Other references used different components [17].

4.3. Software

As an example for such software the NetLab's Graphical User Interface (GUI) is written in Java (initially it was written in LabVIEW). The NetLab has its own dedicated server which is connected on one side to the Internet allowing users to access the remote lab. On the other side some servers communicate with a number of programmable laboratory instruments via the IEEE 488.2 standard interface, also known as the General Purpose Interface Bus (GPIB). These instruments include the digital oscilloscope, the function generator and the digital multi-meter. NetLab GUI is the most distinctive part of this remote lab [5]. From the beginning of its development, it has been designed with the intention of giving students the feeling of working in a real laboratory as much as possible. It has been designed in such way, that it allows users to collaborate during the remote experiments in a similar way as students collaborate in the real laboratory.
As an example for remote laboratory for Circuit theory, a largely composed of Client, LabVIEW Server and Circuit system was used [11].

4.4. Communication

As regards communication between machines, several levels of complexity must be differentiated. The management and total handling become more complicated according to the kind of desired networks functionality and data exchange. This differentiation is often based on the following functions networks: File transfer (File transfer), Execution of programs on other machines (remote execution) and virtual Terminals (Network File System) [12]

4.5. Video Camera

Along with the virtual panel accessed over the internet, the students can also access a video feed from the lab to observe moving parts and the changes in the instrument as parameters are varied on the virtual panel controlling the instrument. [9]. Zooming in on a detail can be activated by the user. Cameras can be used also for live remote conferencing among students group in the experiment or with the tutor.

5 TESTING AND EVALUATION

5.1. Tutor Assistance

Tutor's job in assisting students among other things lie in giving information and assistance in questions concerning the content or referring to technical problems as well as organizing the learning process and its time limits [4]. Even when working independently to perform experiments or program devices, students typically need help at some time by fellow students or a tutor [4]. In typical local laboratories, students can get assistance from a local human tutor. In a remote laboratory a tele-tutor, who can communicate by synchronous communications tools with the students, should be an element of the instructional support [13]. When remote laboratories are used on an international scale, asynchronous communication will be needed more than to date. Tutors will assign tasks to students, support them in lab preparation and grade lab reports using asynchronous communication [13]. Even when working independently to perform experiments or program devices, students typically need help at some time by fellow students or a tutor [4].

5.2 Evaluation

Different evaluation methods were reported in literature. Those include learning success, audio and video recording, screen capturing and interviews [14]. Some authors investigated different scenarios. In these scenarios teams have shown that they are able to transfer theoretical knowledge to concrete problem situations. Additionally the online teams have noticed that remote diagnosis and maintenance could be important for them in the future [14].

Research for evaluation of remote lab outcome compared to ordinary laboratory is still going on. The outcome is to be based upon actual comparison of two groups of students who perform the same experiments in different ways [15]
New technologies may call for new forms of coordination to augment or compensate for the potential isolation of students engaged in remote learning [1].
It is the belief of some authors that if the current level of remote experiment development continues, it will ultimately become the preferred method of learning for future graduates [16].

5.3. Tele-presence operation

The feeling of being present at the experimental site can be further enhanced by the transmission of sound and video images from the experiment, and by the use of virtual-reality techniques. On the other hand, the fact that the experiment is located far away from the experimenter can also be regarded as an educational asset. There are two reasons for this:
□□□Plants are usually operated 'remotely', by operators located in a control room some distance from the physical plant. Hence, running remote experiments actually reflects the real working conditions.
□□□The trend towards virtual organizations where an operating organization is located in different physical locations is quite apparent in many organizations. This trend can also be anticipated for the most highly skilled technical support staff in many industries. This means that the use of remotely operated experiments is likely to be quite representative of how many control engineers will work in the future. [17].

5.4. Administration

The administrative level of access to the facility should allow a user to have additional capabilities, such as maintenance of available experiments, gathering user activity data, and results of weekly surveys. These application features allow an administrative user to activate or deactivate a given laboratory session or a specific task within a session at the Internet level. Activation of any experiment should be followed by loading of appropriate GUI and connecting the hardware experiment with the facility. [8]

As an example, some references described a system which serves five different remote labs [18]. The initial stage of that lab setup includes a wafer testing station that allows users to both visually inspect and electrically test characteristics of electronic circuits on a wafer. That lab allows users to manipulate micro-probes in order to electrically probe at different points of a circuit under a microscope [15].

Different management issues are usually addressed, e.g. registration and logging of students and tutor.

5.5. Experiment Service Provider

When remote laboratories reach a mature status, a lot of work may be left to specialized companies or what we call experiment service providers. The usage can be for research, education, on-the-job training etc. The access to these facilities is to be offered via such independent operating companies. Such companies my offer e-commerce services like booking, access control, invoicing, dispute resolution, quality control, customer evaluation services, marketing, software provision and a unified Lab Portal on global basis [5].

5.6. Collaborative Learning

Students working together as remote group motivate the help among them and acquire social competence in team work. When students are located at different places they also acquire skills in remote collaboration [4]. Evaluation of such relationship has to be investigated further. Working with remote experiments will develop engineering skills like remote maintenance of devices. When students work in distributed teams they also learn how to act in remote collaboration [4].

5.7. Security

Security may be achieved by design, so as to operate the equipment within the allowable ranges of its operation, e.g. current limits, voltage limits, power consumption limits, temperature limits and speed limits for moving parts, etc.

From software point of view every step should be tested from security point of view so as not to exceed the limits of safe operation, as well as security to limit the access to the system by user names and passwords.

5.8 International Collaboration

International collaboration through the internet using e-lab has been joined recently by students from Singapore, Sweden and Portugal. Skill gained from such collaboration will enable graduates to work effectively as a part of international engineering teams in the future [5]. Participants act in distributed virtual teams and communicate with each other and a tutor by synchronous tools like videoconference and chat [4].

6 AN EXAMPLE

At the department of electrical engineering at Jordan University, five different modules were constructed through four final year projects. These modules are:

6.1. DC Circuit Module:

A kit of a dc circuit consisting of 7 resistances, 3 dc voltage sources and 10 switches was the basis to perform different dc experiments. With different setups of switches positions, various experiments were set. Current division between parallel connected resistances, voltage division between series connected resistances, Kirchhoff's current law, Kirchhoff's voltage law, superposition theorem, Thevinin's theorem, Norton's theorem and power measurements were among the experiments tried using this kit.

6.2. Transient response and AC Circuit Module:

This module contains resistances, capacitor and inductor which may be connected in various forms to measure the transient response of the RC circuit, RL circuit and RLC circuits. The same module was used for testing the frequency variation response of RC, RL and RLC circuits. Many more experiments are possible with this kit.

6.3. OpAmp Kit:

This kit was used to perform various tests on operational amplifier. Inversion, summation and integration are among such tests.

6.4. Transformer Kit:

This kit is for performing various tests on two winding transformer. DC resistance measurement, open circuit test and short circuit test were set as target experiments using this kit. Some other experiments may be added using this kit like hysteresis loop experiment, excitation current waveform, autotransformer tests and some other experiments.

6.5. DC motor kit:

The aim of this kit was to perform testing of shunt excited dc motor. Control of speed of such motor using armature voltage variation and shunt field control were performed using this kit.

These kits contain a number of measuring techniques, power supplies, switching techniques, GIU's and video transmission using camera. Analog to digital signal interfacing is a common problem need to be addressed in many experiments. MATLAB was used in some experiments as it provides an efficient mathematical tool which was used in some manipulation of measured quantities.

7. CONCLUSIONS

The main conclusion is that carefully designed laboratory experiments together with well designed user interfaces and proper means of communication can result in solutions of remote experimentation which are comparable with local operation of the equipment. Management of remote labs is an important issue in e-learning success. Distance-learning experiments can lead to the same learning results as traditional local lab experiments.

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